QUATERNARY BLIND THRUSTING IN THE SOUTHWESTERN SACRAMENTO VALLEY, CALIFORNIA

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Jeffrey R. Unruh (Dept. of Geology)
Lewis P. Munk (Dept. of Land, Air and Water Resources)
Eldridge M. Moores (Dept. of Geology)
Randal J. Southard (Dept. of Land, Air and Water Resources)

all at: **University of California, Davis 95616**

OBJECTIVES

The goal of this study is to conduct a detailed Quaternary geological evalutation of the southwestern Sacramento Valley. Previous workers (Wong and Ely, 1983; Eaton, 1986; Wentworth and Zoback, 1989) have noted that the seismotectonic setting of this region is similar to the Coalinga area, western San Joaquin Valley, California, where a magnitude 6.7 earthquake occurred on a blind thrust fault in 1983. A sequence of earthquakes that included two M6.0+ mainshocks and at least one M5.0+ aftershock occurred in the southwestern Sacramento Valley in 1892 (Dale, 1977; Toppozada et al., 1981). The source of this sequence is presently enigmatic, but recent work suggests that much of the western Great Valley of California, including the study area, may be characterized as a seismically-active fold and thrust belt (Namson and Davis, 1988; Wentworth and Zoback, 1989). We are pursuing a multi-disciplinary study to test the hypothesis that Quaternary deformation in this region, and possibly the 1892 earthquake sequence, occurred by movement on blind thrusts. Specifically, we intend to:

1) Determine the location and geometry of blind thrusts beneath the southwestern Sacramento Valley through analysis of seismic reflection profiles;
2) Map Quaternary tectonic-geomorphic features in the study area;
3) Relate patterns of surface deformation to the geometry of the underlying thrust system;
4) Place constraints on the rate and timing of uplift due to thrusting using tephrachronology and soil-stratigraphic studies.

PRELIMINARY RESULTS

To date, we have obtained over 75 km of industry seismic reflection data from the Rumsey Hills and Dunnigan Hills areas of the southwestern Sacramento Valley. Figure 1 is a schematic east-west cross-section illustrating the major structural features visible in the reflection profiles. The seismic data clearly image an east-vergent blind thrust at a depth of 4.0 seconds two-way time (approximately 7 km depth, based on proprietary depth-velocity curves) beneath the eastern Rumsey Hills. The thrust can be traced eastward beneath the Dunnigan Hills, where it ramps up to a depth of 3.1-3.1 seconds (approximately 4.5 km). Time-migrated reflection profiles reveal that at least one west-vergent thrust roots in the blind east-vergent thrust beneath the Dunnigan Hills (Figure 1). We interpret this thrust as a backthrust. Projection of the thrust westward suggests that it may surface in the western Rumsey Hills, where numerous west-vergent thrusts have been mapped (Kirby, 1943; Ramirez, 1990). The intersection of the blind, east-vergent thrust and west-vergent backthrust beneath the Dunnigan Hills forms an eastward-tapering underthrust wedge.

Uplift of the Rumsey Hills and Dunnigan Hills during the Quaternary is consistent with east-vergent underthrusting and wedging. West-vergent backthrusts in the Rumsey Hills are mapped as placing Cretaceous strata over Plio-Pleistocene conglomerates (Kirby, 1943; Taylor, 1955). Asymmetric fault-bend folding above the backthrusts, visible in the seismic reflection data, has uplifted and folded the Dunnigan Hills during Quaternary time. The apparent lack of surface deformation east of the Dunnigan Hills suggests that displacement on the blind east-vergent thrust is transferred to the backthrusts so that the strata east of the wedge tip remained "pinned" and essentially undeformed.

We are currently negotiating with a major oil company to obtain additional seismic data from this region and other areas of the southwestern Sacramento Valley. Using this data, we expect to clarify certain elements of our preliminary structural interpretation, and determine how far along strike individual thrusts extend.

We have also begun a study of tectonic-geomorphic development in the Rumsey Hills/Dunnigan Hills region. Our goal is to directly relate patterns of surface deformation to the geometry of the underlying blind thrusts. Based on reconnaissance studies, we have identified flights of alluvial terraces developed adjacent to several streams which cross the Rumsey Hills and Dunnigan Hills structures. Each terrace may be considered an originally horizontal or gently-dipping datum. Relative uplift and tilting of the terraces may be inferred by comparison with the profile of the modern stream channel. We anticipate that the terraces record a history of progressive deformation during evolution of the Rumsey Hills and Dunnigan Hills. Beginning in spring of 1991, we will map and survey these terraces. Drawing on Suppe's (1985) kinematic models for fault-bend and fault-propagation folding, we wish to test the hypothesis that the geometry of the underlying thrusts will give rise to distinctive patterns of surface uplift and tilting. The kinematic models predict that: 1) incremental uplift occurs above ramps in thrusts; 2) incremental tilting of horizontal material surfaces in the hanging wall occurs when the surfaces pass through kink bands tied to changes in fault dip; and 3) progressive deformation is different for fault-bend and fault-propagation folds. We will modify these models as appropriate for the underthrust wedge geometry observed in the study area. We will compare the observed patterns of surface deformation with predictions from models based on analysis of seismic reflection data. We seek to determine if general, geomorphic criteria can be developed to infer the gross geometry of active blind thrusts from patterns of surface deformation.

As a complimentary study, we will attempt to determine the rate of deformation by estimating the ages of stable geomorphic surfaces in the Dunnigan Hills. Relative ages will be determined by mapping morpho-stratigraphic units. Estimates of absolute age will be constrained by soil-stratigraphic relationships, magnetostratigraphy, tephrachronology, and possibly by radiocarbon dating. We have mapped several exposures of two previously undescribed Plio-Pleistocene tuffs in the study area. The tuffs have been sampled by Andre Sarna-Wojcicki (USGS) for correlation with other known Quaternary tephra in the western United States, or radiometric dating. The soil stratigraphic study is on-going and several representative sites have been selected for detailed description, sampling and laboratory characterization.

We have completed a detailed study of the longitudinal profiles of three streams crossing the Dunnigan Hills and related Quaternary structures to the south (Munk and others, 1991). The stream profiles are distinctly convex across the Quaternary structures, a departure from the smooth, concave-up profile of an idealized graded stream. For comparison, three streams in the southwestern Sacramento Valley were also chosen for study that do not cross any areas of obvious Quaternary uplift. We developed best-fit curves to describe the longitudinal profiles using non-linear regressive methods (exponential decay model, y=a (exp)^b). Regression coefficients (r^2=0.95 to 0.99) indicate that this model is appropriate for describing these stream reaches. Hypothesis testing revealed that the model-derived decay parameters (b) for the streams crossing the Quaternary structures were statistically different from the control streams at the 95% confidence interval. Testing also indicated that the decay parameter (b) was not different *within* the two groups at a 95% confidence interval. We interpret the localized deviations from convexity for streams crossing the Quaternary structures as evidence for relatively recent uplift.

Based on our preliminary work in the Rumsey Hills and Dunnigan Hills regions, we believe that the 1892 Winters/Vacaville earthquake sequence probably occurred by movement on one or more blind thrusts beneath the southwestern Sacramento Valley. If so, the faults should conservatively be considered active and capable of generating moderate to large magnitude earthquakes.

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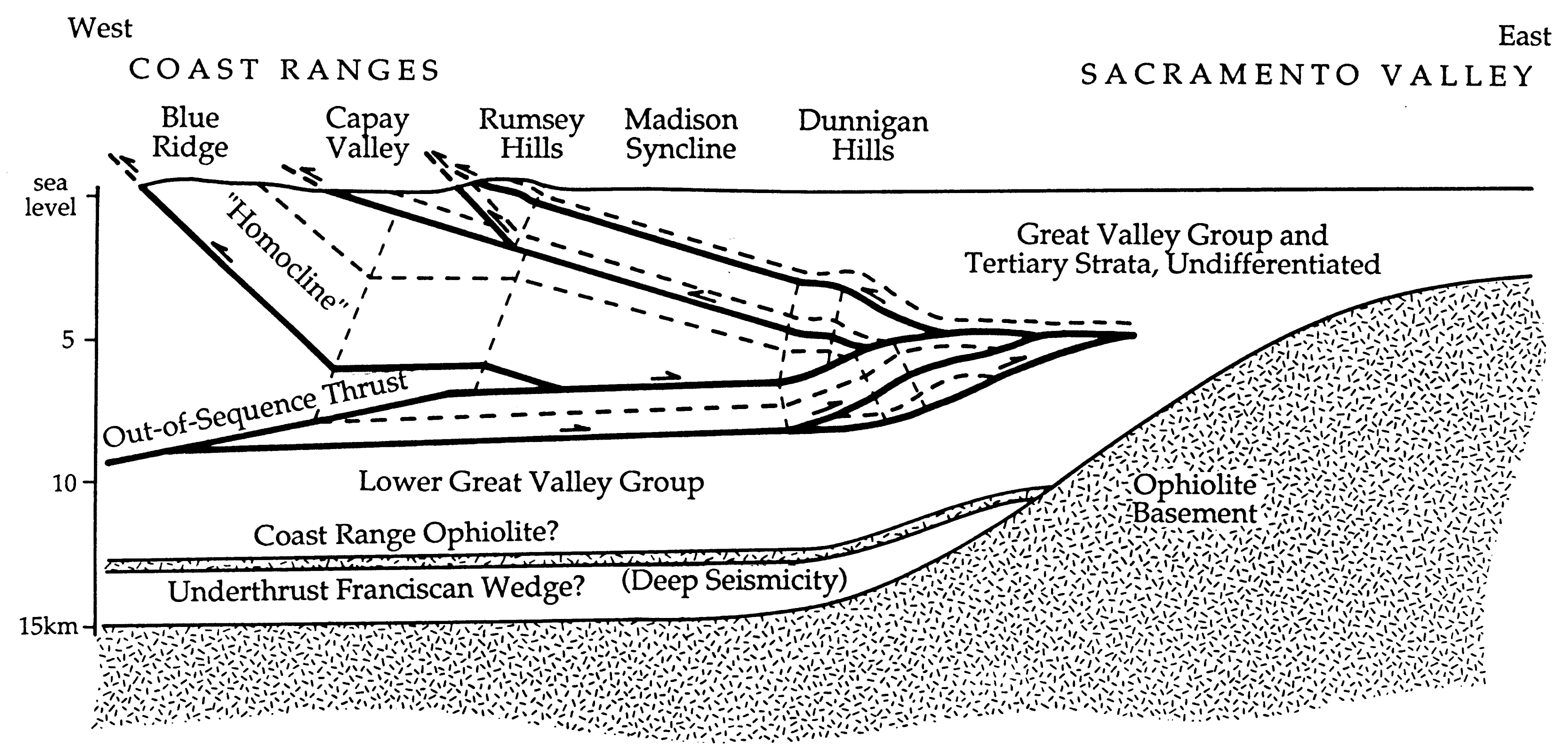

FIGURE 1: Schematic east-west cross-section illustrating the major structures beneath the southwestern Sacramento Valley inferred from analysis of industry seismic reflection profiles and other data. Dashed lines indicate the dip of seismic reflection fabric and are not intended to represent a specific stratigraphic horizon. No vertical exaggeration.